U.S. Army Armament Research, Development, and Engineering Center

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EFFECTIVENESS TESTING AND EVALUATION OF NON-LETHAL WEAPONS FOR CROWD MANAGEMENT

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Target Behavioral Response Laboratory (TBRL) has developed methods of quantitative testing and evaluation of non-lethal weapons (NLWs) against intended targets in crowd scenarios. These methods include appropriate experimental design and data collection, standardized quantitative metrics, data processing and statistical analyses to evaluate relative non-lethal weapons performance, irrespective of weapon type, platform, or energy. The following results from controlled laboratory experimentation are a demonstration of the depth of analyses that result from these laboratory methods for the testing and evaluation of NLWs. To our knowledge, this is the first reporting of quantitative metrics and statistical analyses of non-lethal weapons performance in a crowd scenario. While the results of this specific experiment are not meant to be broadly interpreted as relative effectiveness of stimuli types or device per se, when applied to fielded and candidate devices, these methods will yield comprehensible and actionable information on relative effectiveness. These methods may provide guidelines for testing and evaluation of NLWs. Moreover the results indicate that: 1) controlled laboratory testing of non-lethal weapons against intended targets is possible, 2) quantitative metrics on crowd response to non-lethal weapons fire can be derived, 3) standard quantitative metrics on crowd response to non-lethal weapons can be derived regardless of weapon type, platform, or energy, 4) quantitative metrics on crowd response to non-lethal weapons can be subjected to standard statistical analyses that yield evaluations of performance, 5) the results of these statistical analyses can be used to evaluate and compare the performance of non-lethal weapons, 6) these procedures are easily repeatable for effectiveness testing and evaluation of existing and candidate non-lethal weapons, 7) these procedures are easily adaptable for effectiveness testing and evaluation of existing and candidate non-lethal weapons in TBRL's existing higher-fidelity outdoor testbeds.

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ARDEC's Role


RESEARCH


DEVELOPMENT


PRODUCTION


FIELD SUPPORT


DEMILITARIZATION

Advanced Weapons:
Line of sight/beyond line of sight fire; non line of sight fire; scalable effects; non-lethal; directed energy; autonomous weapons

Ammunition:
Small, medium, large caliber; propellants; explosives; pyrotechnics; warheads; insensitive munitions; logistics; packaging; fuzes; environmental technologies and explosive ordnance disposal

Fire Control:
Battlefield digitization; embedded system software; aero ballistics and telemetry

ARDEC provides the technology for over 90% of the Army's lethality and a significant amount of support for other services' lethality

National Quality Award 2007 Award Recipient

Military Need for Crowd Behavior Research

- The motivations underlying adversarial behavior
- Behavior of contested populations
- How do the behaviors of populations vary cross-culturally?
- What innate human behavior extends across cultural boundaries?

What is "Effectiveness" in a Non-lethal Weapon

- Effectiveness of a non-lethal weapon is assessed by examining the crowd's behavioral response toward that weapon

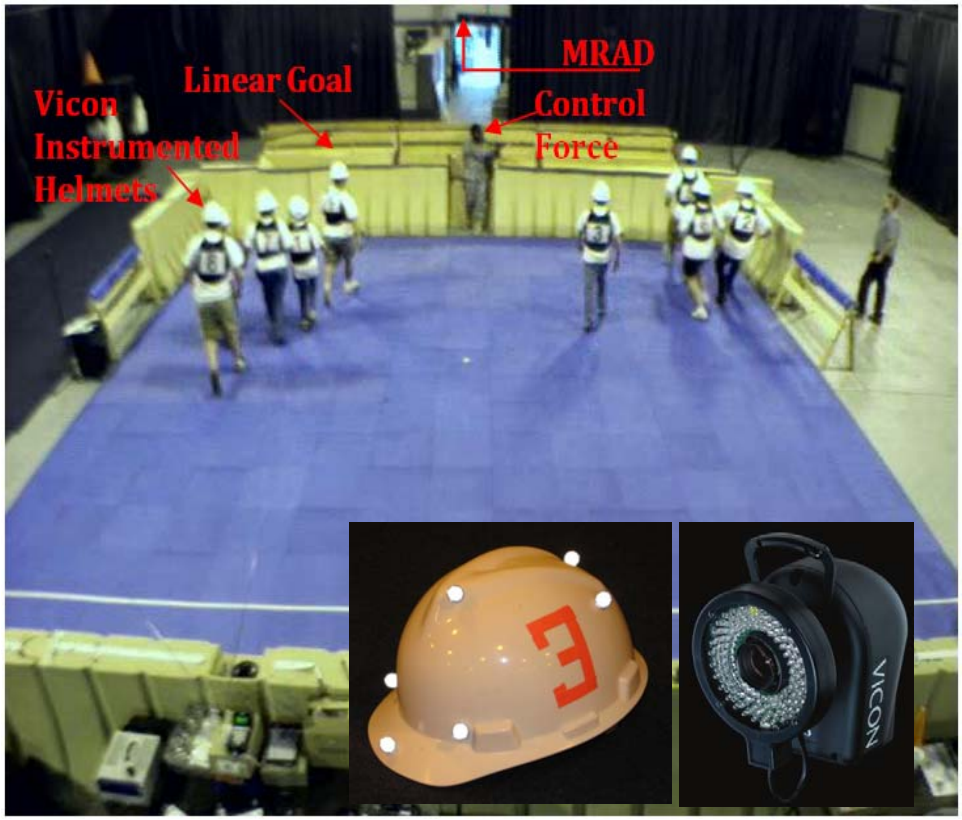
Target Behavioral Response Laboratory

- The Target Behavioral Response Laboratory (TBRL) has developed methods of quantitative testing and evaluation of non-lethal weapons (NLWs) against intended targets in crowd scenarios

- These methods include appropriate experimental design and data collection, standardized quantitative metrics, data processing and statistical analyses to evaluate relative non-lethal weapons performance, irrespective of weapon type, platform, or energy

Crowd Behavior Research at TBRL

- Human behavior can be explained as attractions and repulsions toward and away from goals (Lewin, 1935)
- Crowd Behavioral Test-Bed used to gather:
  - locomotive
  - psychosocial
  - effectiveness data
- Data gathered to develop models that use vector regression methods to identify attributes of a crowd that influence predictive variables



Data Measurement

- Vicon V8i system
- 24 cameras
- 120 fps
- Optical tracking of retro reflective markers (ø14mm)
- Marker error <10mm
- Subjects
  - Unique Helmets
  - XYZ location + 3DOF orientation of head
- Control Force
  - Head & Torso
  - Capability for weapon

Courtesy Vicon

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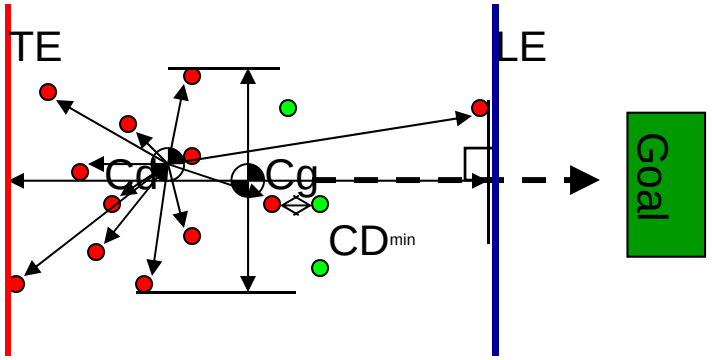
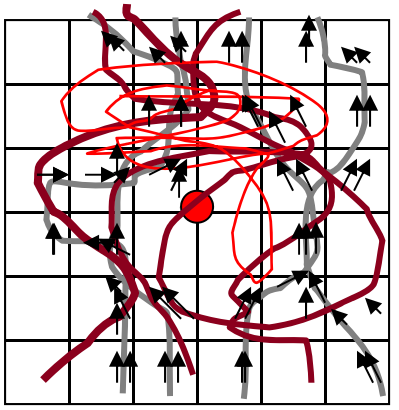
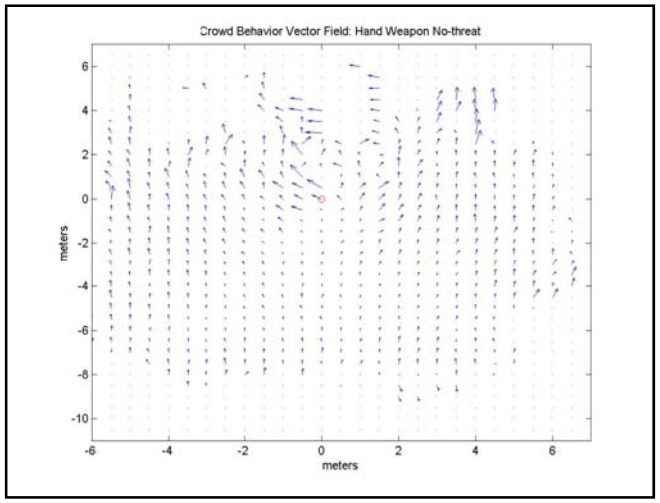
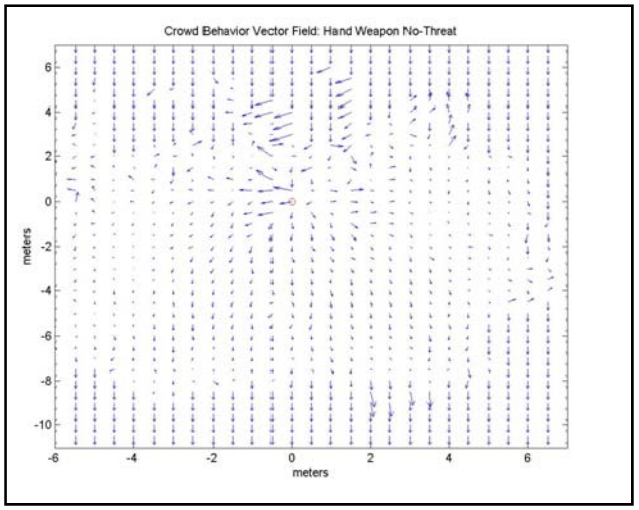
Crowd Metrics









Experimental Conditions

- Crowds with up to 25 subjects
- Scenario consisted of the crowd throwing simulated rocks into a linear target while the target was defended by a non-lethal device:
  - No Defense (Baseline)
  - MRAD
  - Handheld stand-off NLW operated by Control Force
    - Simulated Projectile Weapon
    - Simulated Handheld Directed Energy NLW (VDE)
  - Simulated Invisibly located Directed Energy NLW (IDE)

Hypotheses

- Compared with a less effective weapon, the more effective non-lethal weapon:
  - induces more of the crowd to stay where they are
  - makes people more hesitant to approach
  - makes people slower when approaching
  - makes people spend less time in the line of fire
  - keeps them farther away from the protected area

Behavioral Constructs to Variables

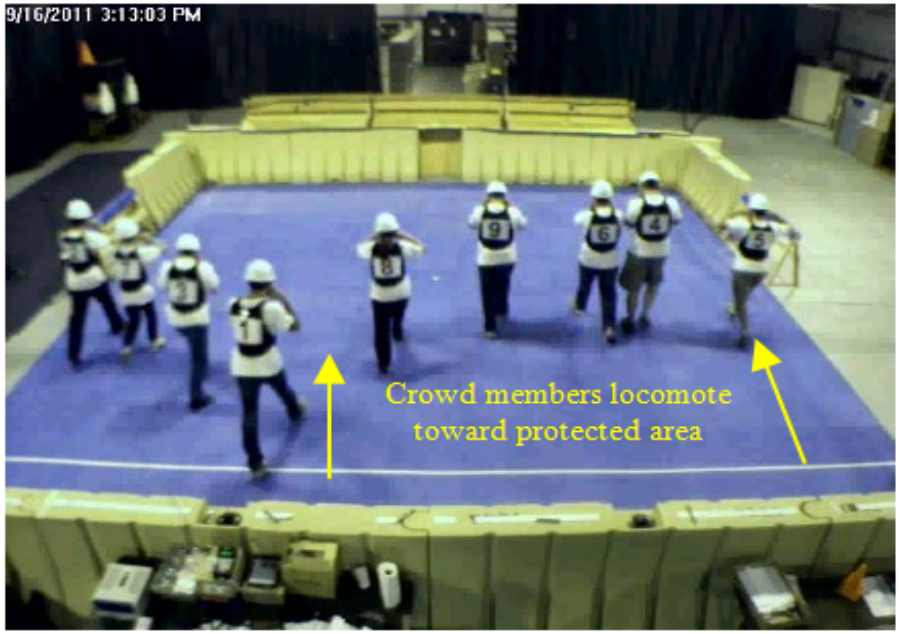
- These behavioral constructs were translated into mathematical terms for statistical analyses
- The derived variables representing these behavioral constructs were, respectively
  - percentage of people in the crowd who never initiated approach
    - (*% Suppressed*)
  - mean time from start to time when people initiated approach
    - *(Hesitancy)*
  - speed of the centroid of the crowd on approach to the target
    - (*Approach Speed)*
  - the shortest distance from the leading edge of the crowd to the target
    - *(Closest Approach)*
  - time the centroid of the crowd spent in the line of fire
    - *(Time Under Fire)*

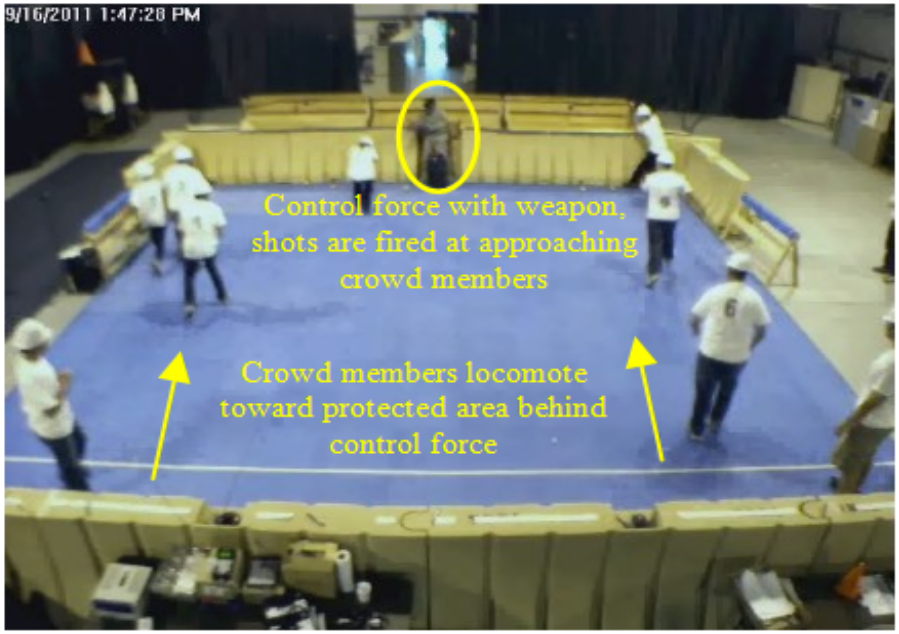
Methods

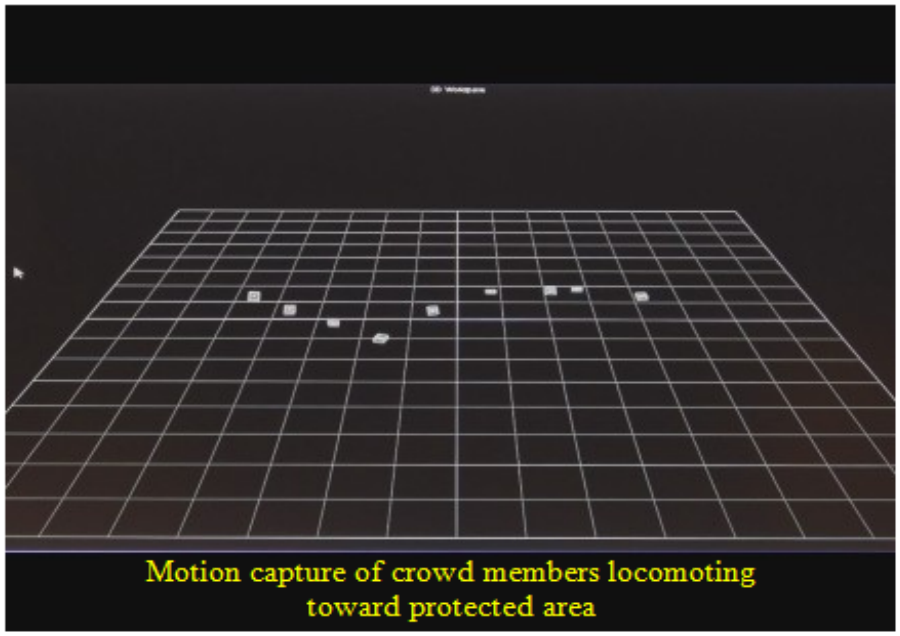
- All procedures were approved by the local human subjects research ethics board (ARDEC IRB #10-0002, “Effectiveness Testing for Crowd Management with Non-Lethal Weapons”)
- Participants were recruited from the general population to participate in an investigation on “Crowd Movement”
- Fifty-two healthy men and women participated in one of seven experimental sessions, each held on a different test day

Research Design

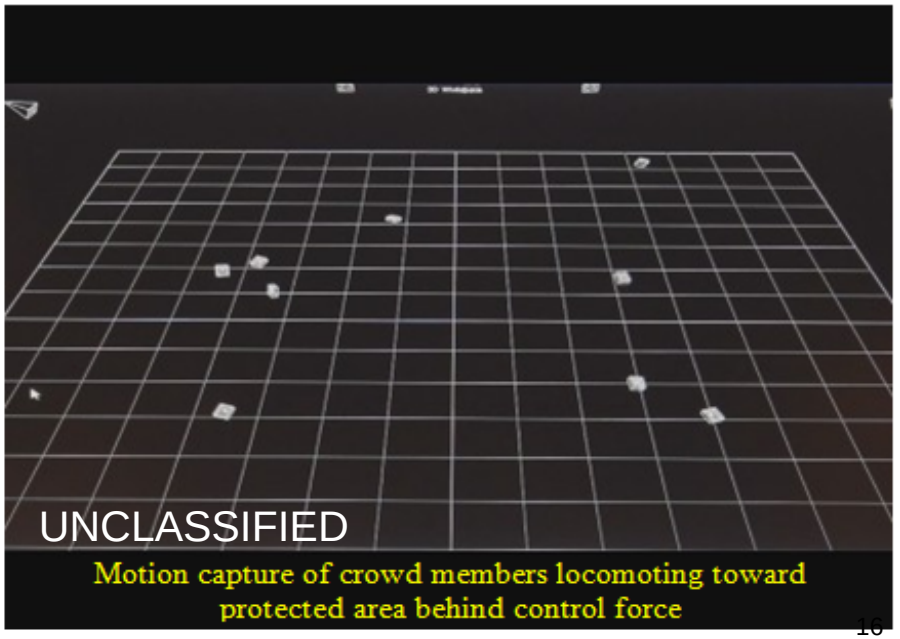
- Subjects targeted a protected area with simulated rocks for points which represented money
- The area was protected with control force tactics in an attempt to cause the subjects to lose points (money) or be exposed to aversive noise







Motion capture of crowd members locomoting toward protected area



Motion capture of crowd members locomoting toward protected area behind control force

Simulated Non-lethal Weapons

- The experimental weapon conditions were
  - Projectile (Soldier-carried with low monetary penalty for hits)
  - Directed energy (one simulated dismounted infantry Soldier-carried and one simulated long-range, both with high monetary penalties for hits)
  - Fielded acoustic weapon

Research Design

- After two no-weapon comparison baselines, each directed-energy and projectile weapon condition was tested four times (4 trials); the acoustic weapon was tested twice (2 trials); order of weapon condition was counterbalanced

- During the trials of the experiment, a computer recorded the subjects' location, orientation, and locomotion through the test bed

Analyses

- Data were analyzed using multivariate repeated-measures linear regression methods
  - First, omnibus regressions were run comparing the no-weapon baseline condition with each of the weapon conditions on all five effectiveness measures (% Suppression, Hesitancy, Approach Speed, Closest Approach, Time Under Fire) with the experimental design condition (No-Weapon vs. Weapon) x trial
    - These analyses were run separately for the acoustic, dismounted directed-energy, long-range directed-energy, and projectile weapons
  - Second, those weapon conditions that were found to be significantly different from baseline were run again in another similar omnibus regression comparing performance among the weapons
    - Regression analyses were run on change scores derived from the difference in effectiveness metrics from baseline and under the weapon conditions, with the design weapon (Dismounted Directed-Energy, Long-Range Directed-Energy, Projectile) x trial

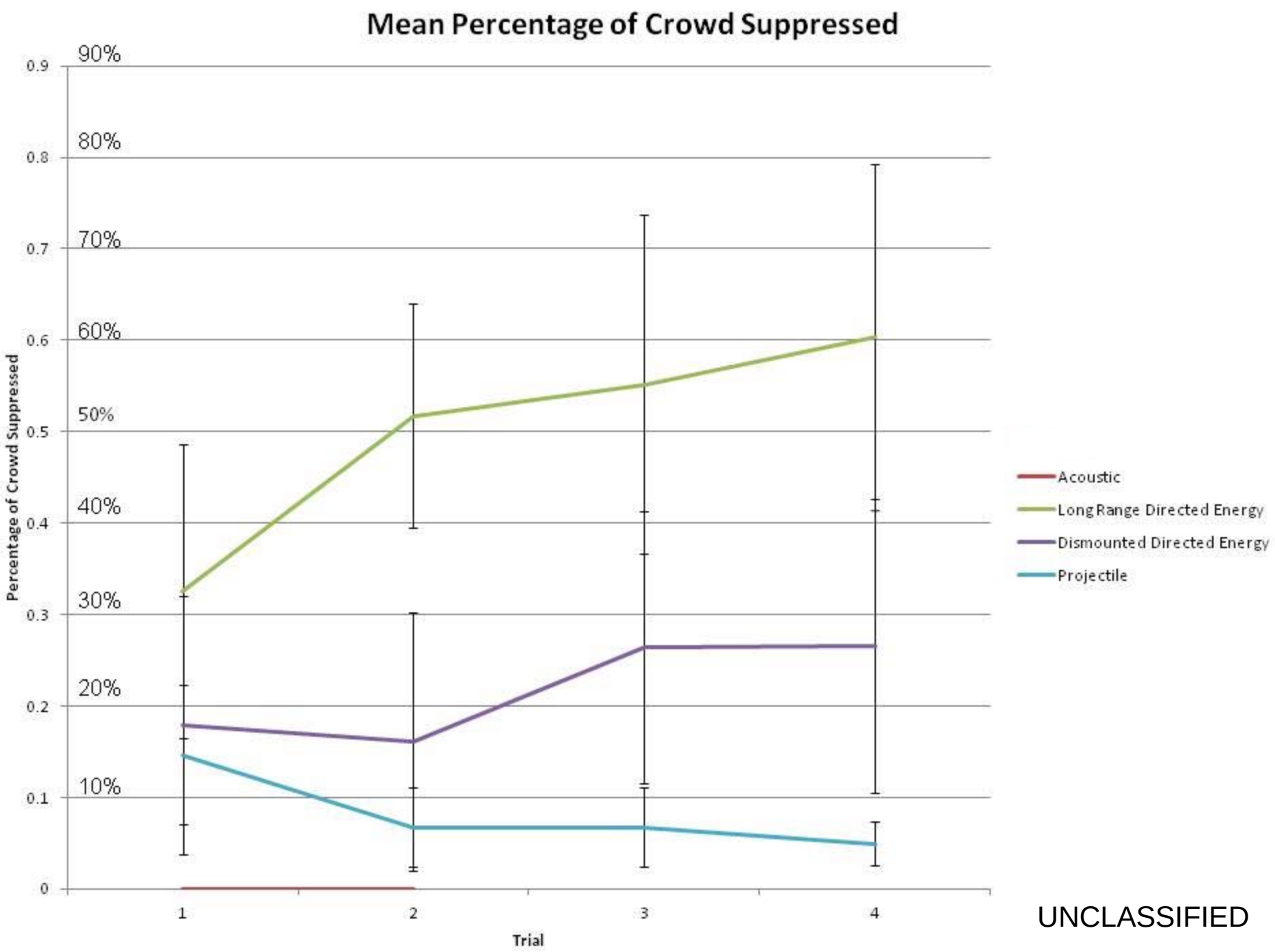
Results: Multivariate, Univariate, Within-Subjects Contrasts

- Multivariate-level analyses indicated a significant overall difference in the effectiveness measures among the weapon conditions ($F_{10,18}$= 3.08, p<.05), but the acoustic weapon had the same effect as no weapon at all
- Univariate analyses indicated that the weapons differed significantly in % Suppression ($F_{2,12}$=3.97, p<.05) and Hesitancy ($F_{2,12}$=3.97, p<.05 also)
- Within-subject contrasts indicated that, compared with the projectile weapon condition, the long-range directed-energy weapon condition was associated with greater % Suppression ($F_{1,6}$=6.14, p<.05) and greater Hesitancy ($F_{1,6}$=6.14, p<.05 also)

Results: % Suppression

- Univariate analyses indicated that the weapons differed significantly in % Suppression ($F2,12=3.97$, $p<.05$) Within-subject contrasts indicated that, compared with the projectile weapon condition, the long-range directed-energy weapon condition was associated with greater % Suppression ($F1,6=6.14$, $p<.05$)

- Following slide shows this graph



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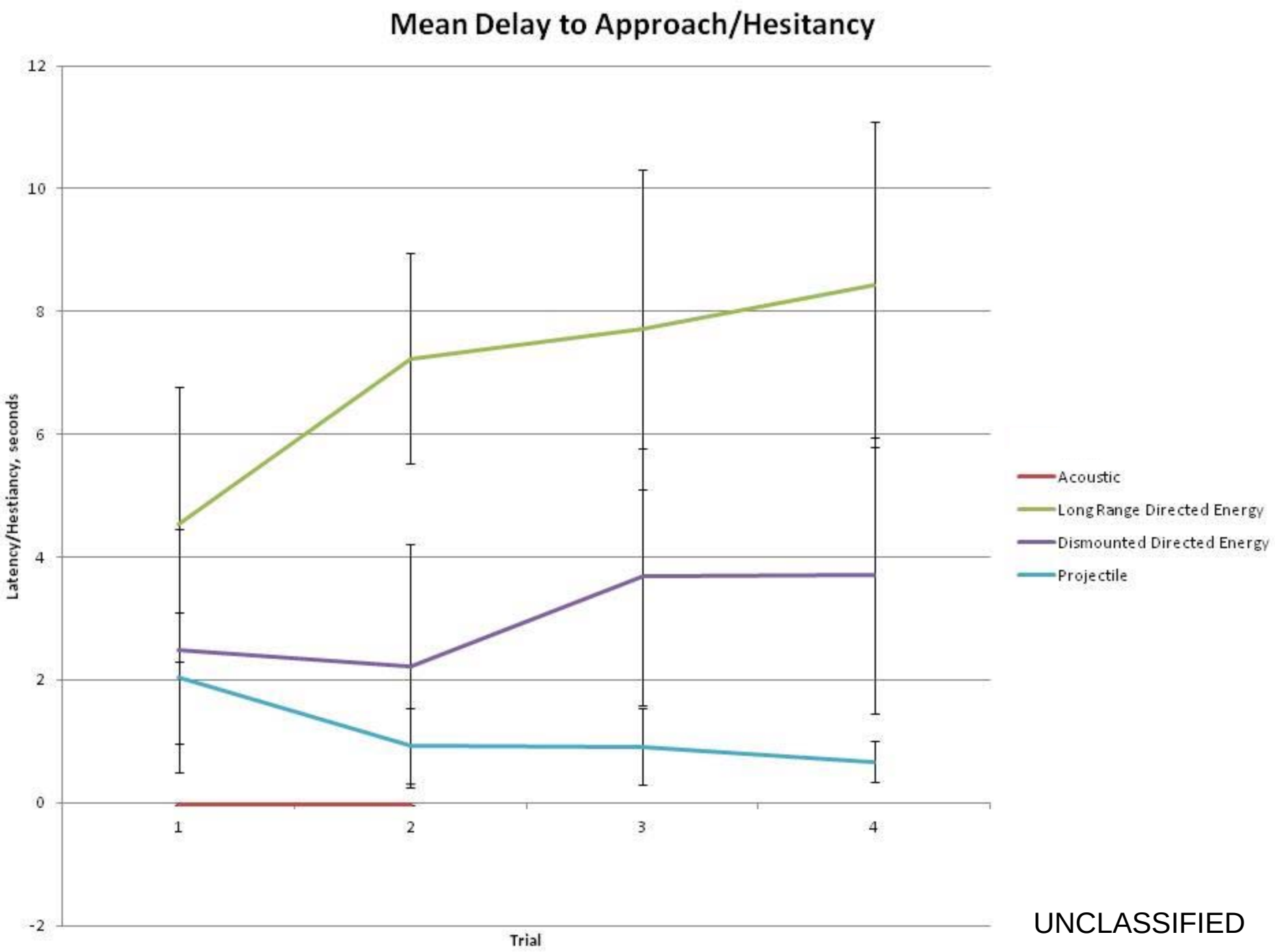
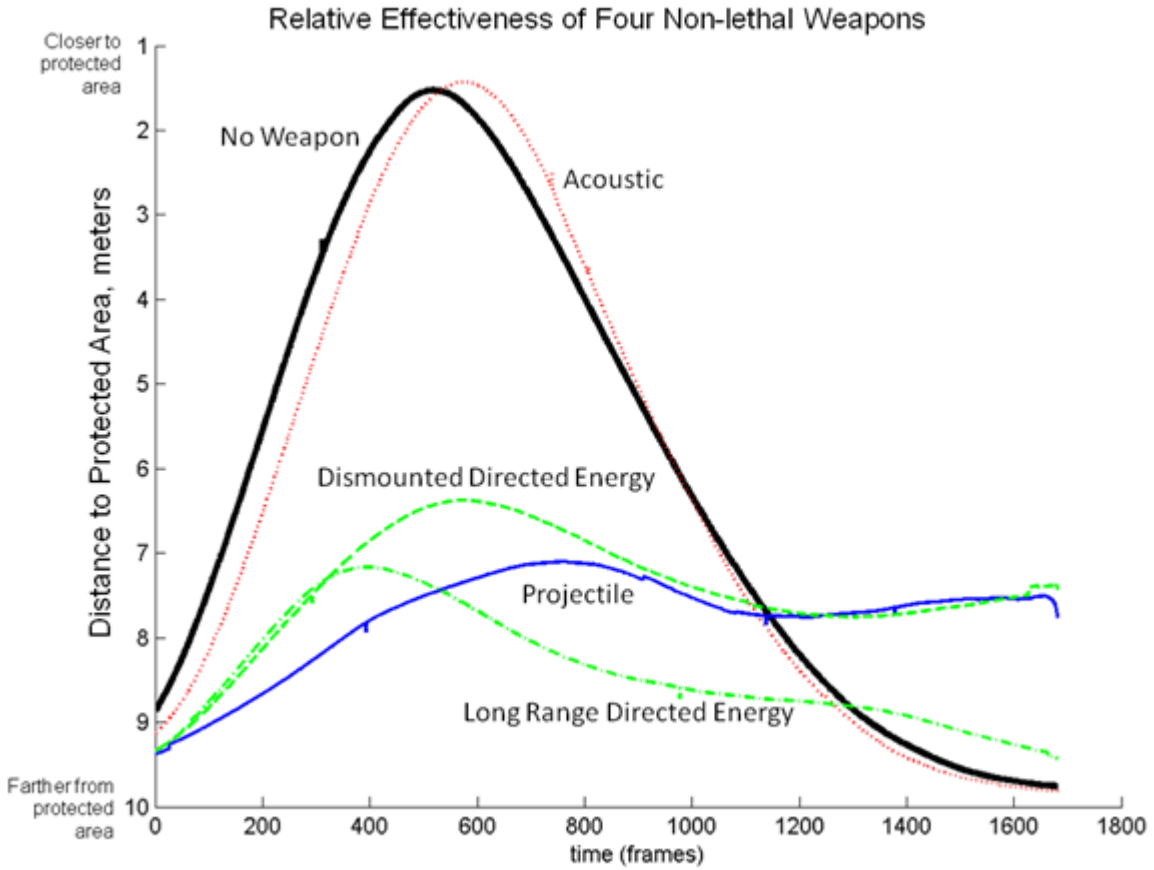
Results: Hesitancy

- Univariate analyses indicated that the weapons differed significantly in Hesitancy ($F2,12=3.97$, $p<.05$)
- Within-subject contrasts indicated that, compared with the projectile weapon condition, the long-range directed-energy weapon condition was associated with Hesitancy ($F1,6=6.14$, $p<.05$ also)
- Following slide shows this graph



Results: Distance from Protected Area by Weapon-type over time



The key NLW effectiveness metric is how well the weapon keeps people away from a protected area

Non-lethal Weapon Effectiveness Testing with Crowds

- To our knowledge, this is the first reporting of quantitative metrics and statistical analyses of non-lethal weapons performance in a crowd scenario
- While the results of this specific experiment are not meant to be broadly interpreted as relative effectiveness of stimuli types or device per se, when applied to fielded and candidate devices, these methods will yield comprehensible and actionable information on relative effectiveness
- These methods may provide guidelines for testing and evaluation of NLWs

Conclusions

- Controlled laboratory testing of non-lethal weapons against intended targets is possible
- Quantitative metrics on crowd response to non-lethal weapons fire can be derived
- Standard quantitative metrics on crowd response to non-lethal weapons can be derived regardless of weapon type, platform, or energy
- Quantitative metrics on crowd response to non-lethal weapons can be subjected to standard statistical analyses that yield evaluations of performance
- The results of these statistical analyses can be used to evaluate and compare the performance of non-lethal weapons
- These procedures are easily repeatable for effectiveness testing and evaluation of existing and candidate non-lethal weapons
- These procedures are easily adaptable for effectiveness testing and evaluation of existing and candidate non-lethal weapons in TBRL's existing higher-fidelity outdoor test beds

Target Behavioral Response Laboratory MORSS Presentations

- Virtual Employment Test Bed: Operational Research and Systems Analysis to Test Armaments Designs Early in the Life Cycle
- Method and Process for the Creation of modeling and Simulation Tools for Human Crowd Behavior
- Squad Modeling and Simulation for Analysis of Materiel and Personnel Solutions
- The Squad Performance Test Bed
- Crowd Characteristics and Management with Non-Lethal Weapons: A Soldier Survey
- Effectiveness Testing and Evaluation of Non-lethal Weapons for Crowd Management
- Effects of Control Force Number, Threat, And Weapon Type on Crowd Behavior

Questions?

US Army - Target Behavioral Response Lab

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